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Wideband (8 GHz GBW) pulse amplifier for the integrated camera of the Cherenkov Telescope Array

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A fully differential wideband amplifier for the camera of the Cherenkov Telescope Array (CTA) is presented. This amplifier would be part of a new ASIC performing the digitization at 1-3 GS/s with a dynamic range of 16 bits. Input amplifiers have a voltage gain up to 20 and a bandwidth of 400 MHz. Being impossible to design an 8 GHz GBW fully differential operational amplifier in a 0.35 um CMOS technology, an alternative implementation based on HF linearised transconductors is explored. Test results show that required GBW is achieved, with a linearity error smaller than 1% for a differential output voltage range of 2 V.

Summary

Very high energy gamma-ray astronomy is now a mature field. The community is gathering around the Cherenkov Telescope Array (CTA) consortium, to design and build the next generation ground-based array. A Cherenkov Telescope detects the fast Cherenkov light pulse caused by the electromagnetic shower initiated by the interaction of a very high energy gamma ray in the upper atmosphere. The shower is imaged by a fine grain camera placed at the focal plane of a large mirror. The camera uses fast photomultiplier tubes as photo-detectors, they are read out by a front-end electronics based on an analogue memory which samples and stores the signal at an equivalent frequency of 1 to 3 GHz. The samples are then digitized at a lower frequency and added to give a measurement of the signal charge.
CTA observatory will have about 50-100 IACTs of various sizes and about 1000-4000 channels per camera of 16 bit dynamic range. With such a large number of channels, the CTA electronics will have to face new major challenges, namely simplifying the production and maintenance operations. NECTAr collaboration intends to build a new integrated circuit including most of the discrete components needed so far. A gain in cost and camera performances can be achieved by maximizing the integration of the front-end electronics in an ASIC, a single GHz sampling chip. Here we present the design of the input amplifiers of this ASIC. Starting point is SAM chip, used in HESS telescopes, and fabricated in Austriamicrosystems 0.35 um CMOS technology.
Input amplifiers must have a voltage gain up to 20 and a bandwidth of 400 MHz, i.e. GBW product should be as large as 8 GHz. Designing an amplifier with such a GBW in a 0.35 um CMOS technology is a challenge. Classical OpAmp solutions are not feasible, as largest GBW reported in this technology is well below 1 GHz. Therefore, a different solution, based on high frequency linearized CMOS transconductors, is adopted.
The input stage of the amplifier is a cross-coupled differential MOS pair with a voltage offset, which linearizes the transconductance and determines the gain of the stage. The current of the differential is sensed by a regulated cascade common gate stage acting as a transimpedance amplifier. The output stage must be able to drive relatively large capacitive loads (> 5pF) and it is a closed loop buffer based on a low power class AB OpAmp with high slew rate (1V/ns). The floating voltage supply is based on a closed loop voltage shifter and it is controlled through a bias current. A PTAT current generator drives this current in order to cancel the negative temperature coefficient of the input stage, so an overall gain TC of 0.05 %/K is achieved.
Test results shows that the bandwidth is about 400 MHz when driving the analogue memory input. Gain can be adjusted between 5 and 20, with a linearity error smaller than 1% for a differential output voltage range of 2 V. Noise is below 1.5 LSB.
Integrating input amplifiers together with analogue memory using relatively low cost process allows building affordable multichannel digitizing electronics with large dynamic range (16 bits with double gain system) and a sampling frequency as high as 3 GS/s and a corresponding overall analogue bandwidth exceeding 300 MHz. The application of such system is not limited to gamma-ray astronomy, as it could be applied in other astroparticle instruments, medical instrumentation and even in fast calorimetry.

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